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Haptic Rendering Techniques for Non-Physical, Command Decision Support

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MOTIVATION

The purpose of this paper is to explore non-traditional visualization techniques to assess threat and other variables in command center settings. Not all entities that a commander interacts in real life can be converted to visual medium, which is but just one of the five senses that we have. As an example, sense of threat during a critical situation during a mission cannot be easily communicated with color. Many special skills such as a surgeon using a sharp scalpel or a Pilot negotiating a sharp curve cannot be easily represented in videos or even real time Virtual Environments. We call such systems – non-physical visualization. While elsewhere in this conference we speak about Ontological representation of such events, here some techniques currently underdevelopment to 'visualize' such parameters are presented – including tactile and haptic rendering techniques.

BACKGROUND

Usually visualizing battlefield implies maps, computer screens filled with information and perhaps 3-D displays that represent a wide range of data ranging from intel, logistics and threat information. Decision of a commander is often based on understanding a threat level and calculating a probability of success given all the various sets of information. Some problems related to decision making process are:

- Too much data, too little knowledge
- Complex reasoning that cannot be represented graphically
- Problems in drawing attention to some elements due to information overload
- Trust and confidence in the visual data presented

How adding larger, more complex visualization system can solve much of this is a matter of debate. Is there a more sophisticated way to address some of the problems? In the recent years many interesting new concepts have been developed in the area Physically based modeling which could be used to tackle some of the problems. One such idea is to use haptics rendering and modeling to represent information in a new dimension.

Haptics, from the Greek word *Haptikos* is essentially the sense of touch. More broadly in our context it can be referred to as a resistive or feedback force. With the advent of haptics and the ability to add the sense of touch to a virtual environment, it is now possible to develop completely new set of interfaces for decision support. Information, such as threat, risk, confidence levels can be converted to variety of

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physical sensations that have no equivalent representation in the graphics or visual environments. There are many forms of such force rendering such as; vibration, resistance, viscosity etc.

NEW VISUALIZATION INTERFACE

A new command support interface is proposed here that combine sense of touch with a 3-D interface as shown in the figure 1. A 3-D interface is created with one virtual wall representing a map or terrain of the battlespace or the field where military is involved. On a perpendicular virtual wall a haptic rendering of the space is created. When a certain region is clicked on the map, a blown up representation is presented in haptic wall shown as color grids in the figure. In the haptic wall information such as threat is represented mathematically and converted into vibration or viscosity.

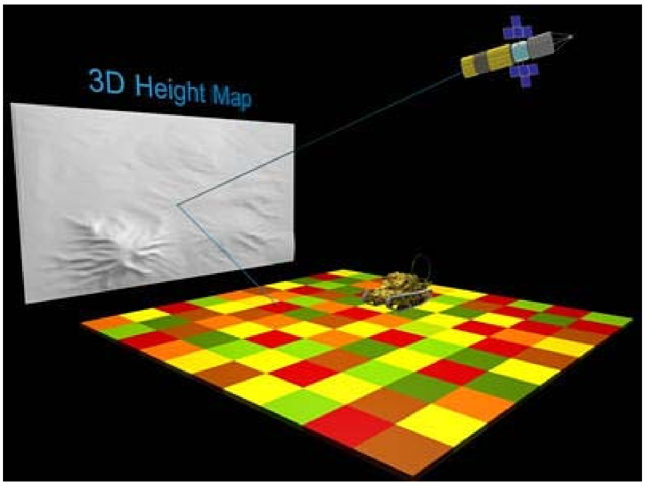

Figure 1: Interface for Haptics in a Control Room.

MODES OF INTERACTION

One example of such a rendering is the probability of the existence of a mine or a cave, which is not obvious from the map or intelligence data. During a decision support activity, the commander uses a Phantom™ type interaction device (figure 2) instead of a mouse to navigate around the battlefield.

Figure 2: Phantom™ – A Commercially Available Haptics Device from Sensable Technologies.

The haptic rendering automatically controls and keeps track of the commander's actions in the given space and dynamically reduces or increases viscosity. Thus when visual map calls for a move in certain direction, existence of high risk will increase the resistance of the navigation task thus reminding the commander about the danger involved in the present decision. By using this system, visual dimension can be freed up to represent other important information.

Results of early research have shown that haptically represented probability of threat while moving towards the goal is a viable control strategy. In a preliminary human subject test it was noticed that users trust and adapt to haptics as to visual feedback system easily.

DISCUSSION

New non-traditional visual interface obviously opens up a number of open-ended questions. We are posing a few here for discussion:

- Will commanders trust haptics or a combination of visual and haptics system?
- What information is suitable for non-traditional visuals?
- What is the range of such devices?
- What is the optimum combination of 3-D VR technology and Haptics?

SYMPOSIA DISCUSSION – PAPER NO: 8

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Comment:
There is the issue of having to know what questions to ask to drill down to more info. There is the trade off between providing enough information to the user without clutter.

Comment:
Response from users is positive, but there is a need to train people to use the techniques.

Non-traditional Visualization

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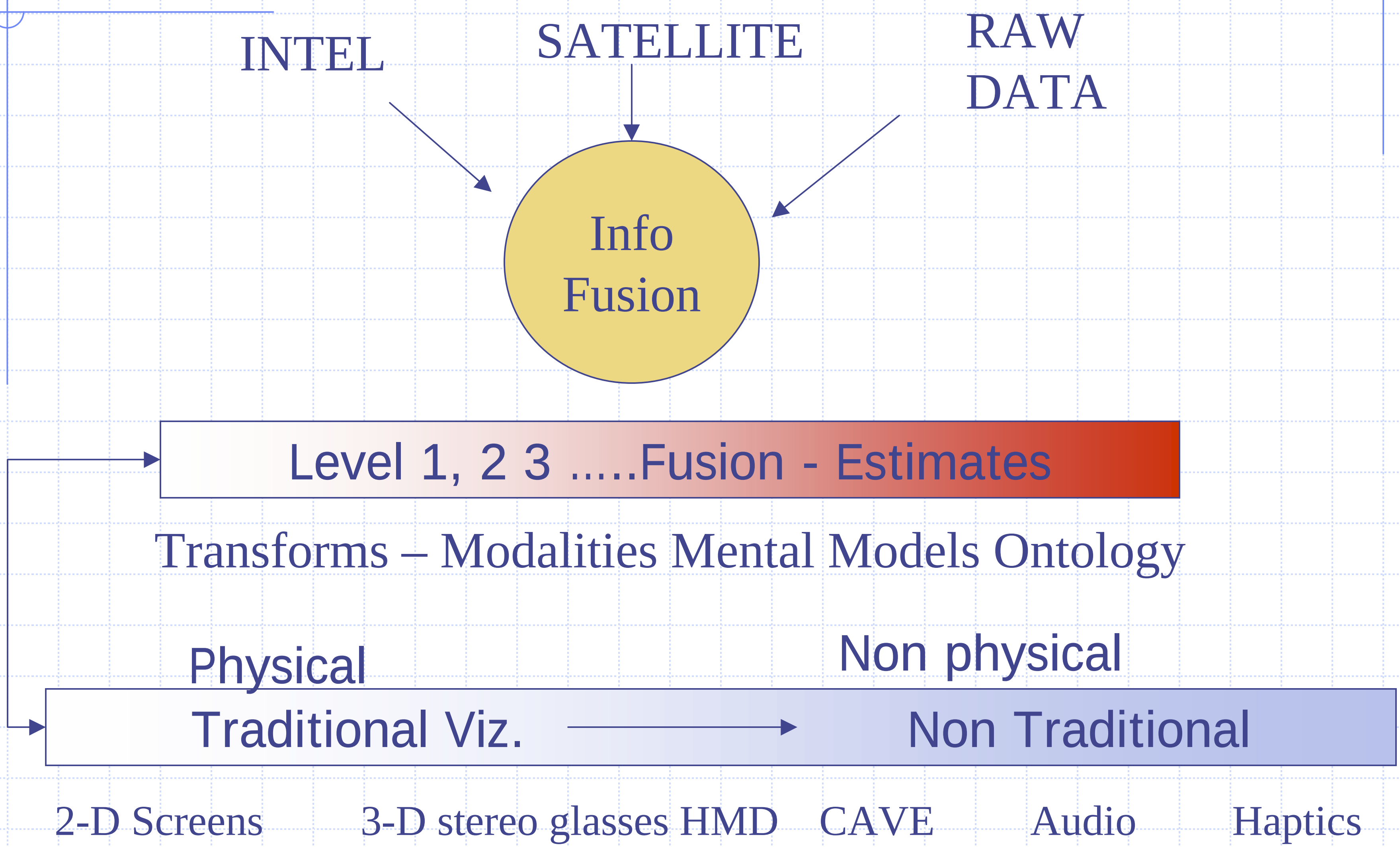
Problems in Large Scale Viz.

- Not every information fusion parameters can be presented visually – Non physical visualization
  - Fear
  - Uncertainty
- 3-D data visualization can overload human cognition
- Visualizing certain data in visual form is non intuitive

Visualization, Info. Fusion and Logical Constructs

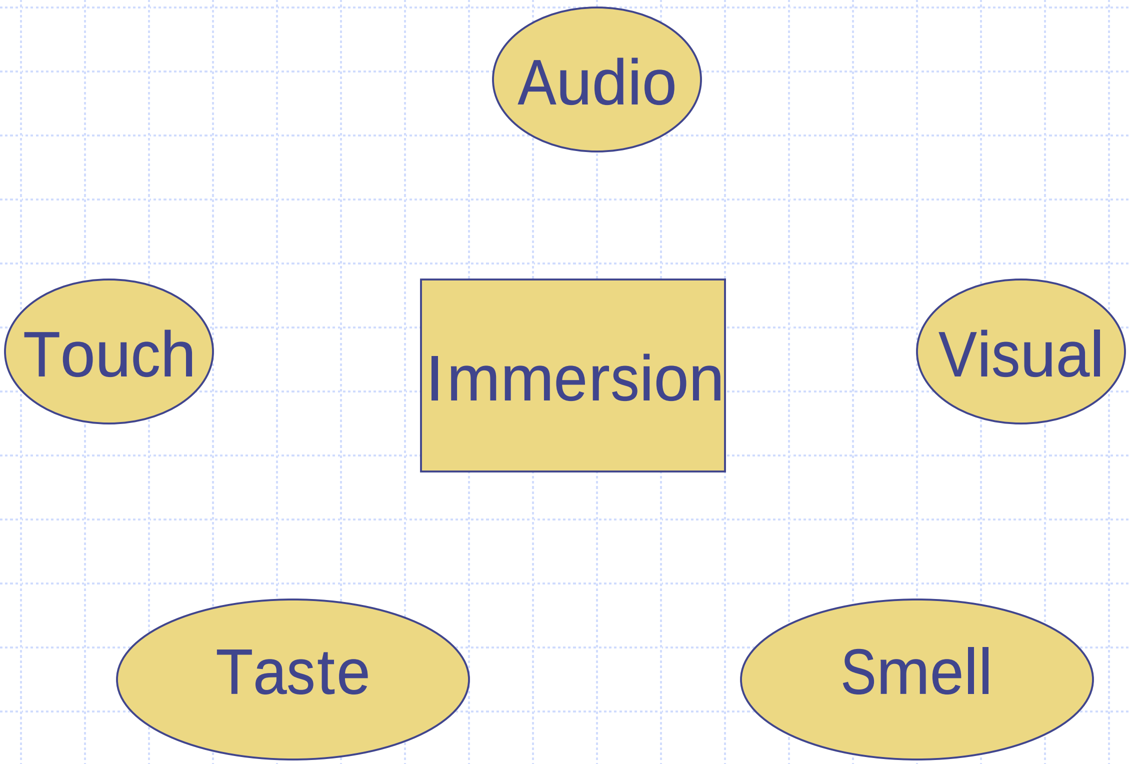


Presentation Agenda

Phases

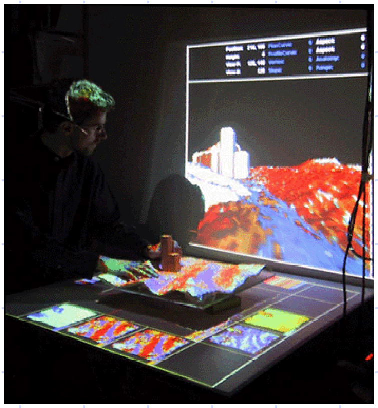
Introduction	Review	Our Work	Conclusion
Focus & goals of Research Potential of Non traditional Viz. Problems in Visualization	– Non traditional – Haptics	–Two experiments	

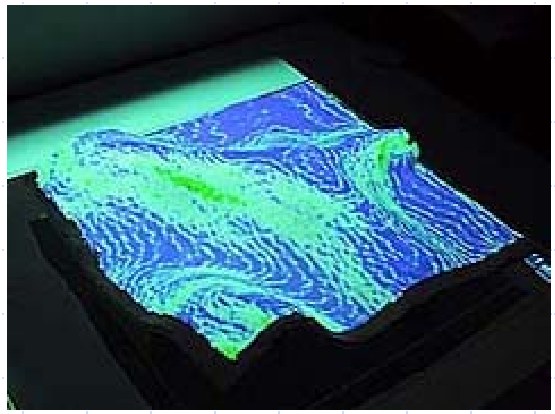
Sensory perceptions



Some Examples

Illuminating Clay





- Landscape models are constructed using a ductile clay support.
- Three-dimensional geometry is captured in real time using a laser scanner.
- From this information simulations such as shadow casting, land erosion, visibility and traveling time are calculated.
- Finally, the results are projected back onto the clay model.

MIT Tangible Media Lab

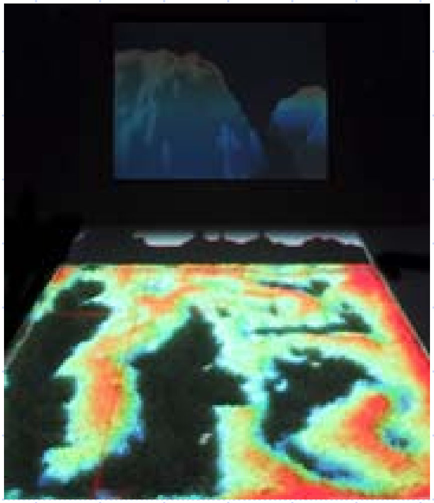
Ambient Room

The ambient ROOM allows users to be aware of background bits using ambient display media such as ambient light, shadow, sound, airflow, water movement in an augmented architectural space.

photo: Brygg Ullmer

Ghostly Presence is an application of the ambientROOM platform. Ghostly Presence explores the subtle representation of the "presence" of people mediated by the physical environment.

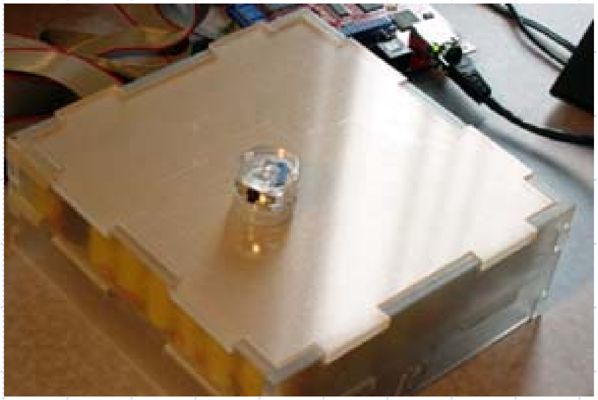
SandScape



SandScape is a tangible interface for designing and understanding landscapes through a variety of computational simulations using sand. Users view these simulations as they are projected on the surface of a sand model that represents the terrain.

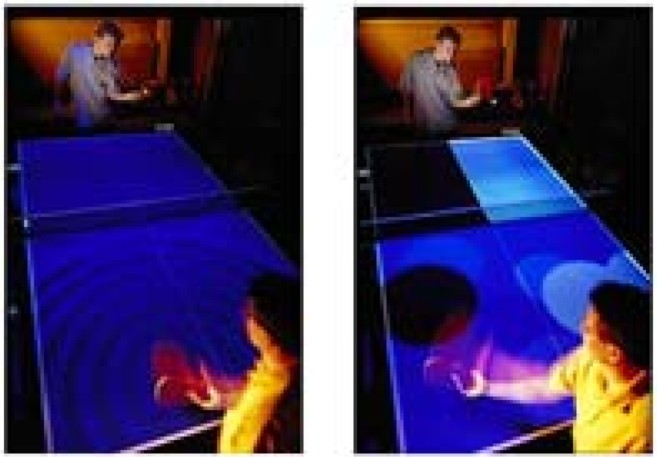
The users can alter the form of the landscape model by manipulating sand while seeing the resultant effects of computational analysis generated and projected on the surface of sand in real-time.

Actuated Workbench



The Actuated Workbench is a device that uses magnetic forces to move objects on a table in two dimensions. It is intended for use with existing tabletop tangible interfaces, providing an additional feedback loop for computer output, and helping to resolve inconsistencies that otherwise arise from the computer's inability to move objects on the table.

Ping Pong Plus

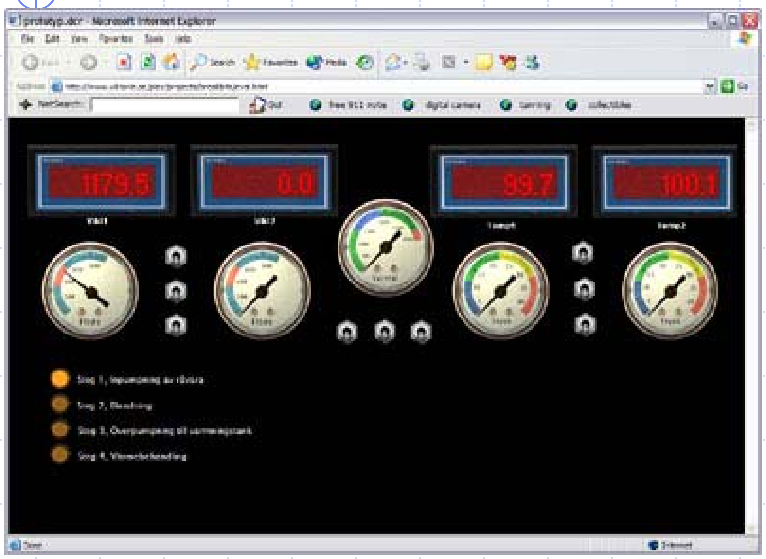


Photos: Webb Chappell

Movie

PingPongPlus is a digitally enhanced version of the classic ping-pong game. It is played with ordinary, un-tethered paddles and balls, and features a "reactive table" that incorporates sensing, sound, and projection technologies. Projectors display patterns of light and shadow on the table; bouncing balls leave images of rippling water; and the rhythm of play drives accompanying music and visuals.

AUDIO BreakBits



The BreakBits interface is intended as a complement to the traditional, mainly graphical, interface. The aim is to help the user concentrate on the most relevant information by giving musical guidance. Rather than directly mapping different sounds to specific events, the purpose is to continuously present information about the status of the computing environment processes in an emotional and discreet manner.

Maintaining focus may be hard or physically impossible (e.g. when turning away from the interface), and the amount of information may be overwhelming. In such a case, the solution to the problem needs to be non-visual, ideally an auditory interface.

BreakBits Prototype: http://www.viktoria.se/play/projects/breakbits/eval.html

Our approach

- Study other sensory modes of data presentation
  - Haptics
  - Tactile

Virtual Lexicon

Haptic feedback

The sensation of weight or resistance in a virtual world.

(from the Greek *haptesthai*, meaning to touch)-Cyber Edge Journal,[1993b]

Tactile Feedback

Sensation applied to the skin, typically in response to contact or other actions in a virtual world.

Examples of Touch

Vibration, Viscosity, Resistance, Constraint, Pain, Temperature

Haptic Devices

Sensable Technologies

Desktop

Premium 1.0 with encoder gimbal

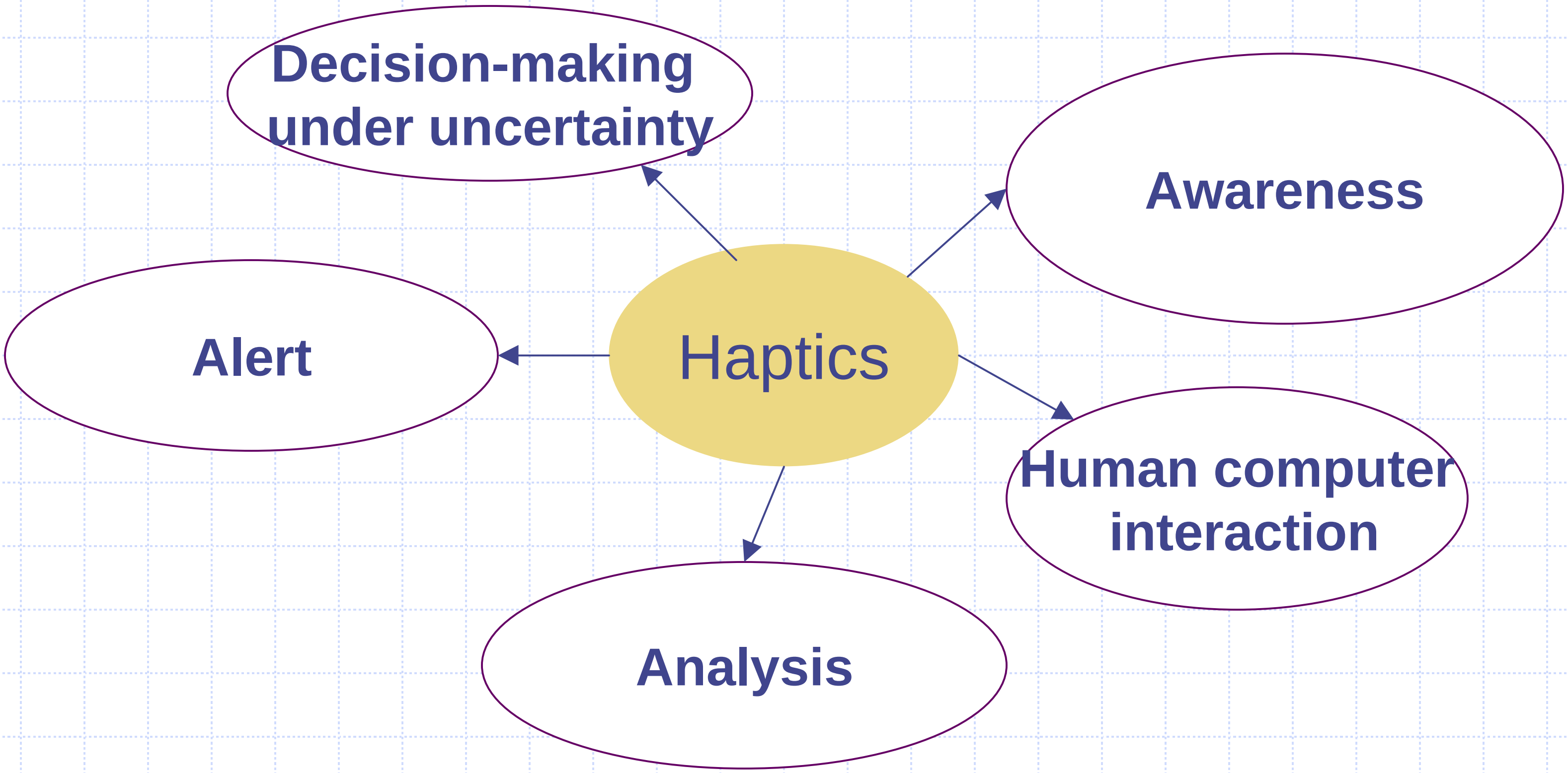
Premium 1.5 with finger stylus

ReachIn Interfaces

Other Devices

- Force Feedback Mouse
- Force Feedback Joystick
- Exoskeleton devices

Potential of Haptics



Application to design space optimization

- One of the ways in which a design problem is solved is by breaking a design process into a series of stages.
- Designer may make decisions at one stage before moving on to subsequent stages.
- Making a decision may simplify the search problem by limiting search to a subset of the overall state space
- Typical of this class of optimization techniques are the pattern search algorithm by Hooke and Jeeves (1961), sequential search by Spendley, Hext and Himsworth (1962).

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Computational algorithm and methodology for haptics based solution

Step 1: Load design space optimization scene graph, with coordinate axes, and constraint contours, with convergence tolerance equal to the radius of the central sphere.

Step 2: Start with an initial vector X_i, and compute function value at the point f_i.

Step 3: Perform a cycle of random moves, by moving the phantom stylus in the design space each along one coordinate direction.

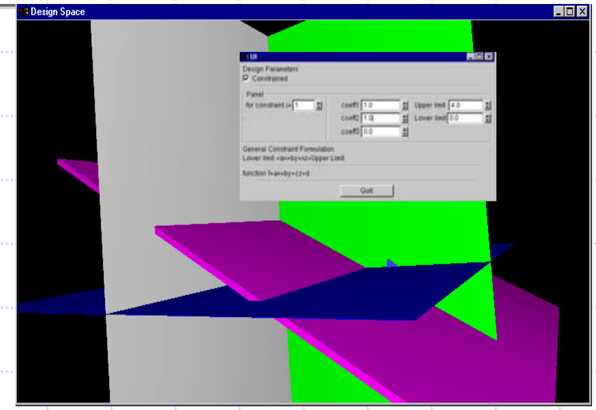
Step 4: Compute $X_i^+ = X_i + \Delta X$, $f_i = f(X_i^+)$, $\Delta f = f_i^+ - f_i$

Step: 5: Return a force given by the force relation

$F_i = -(k^*(|X_i| - |r|)/|X_i|)^* X_i$

Step 6: Use the phantom stylus to guide the designer in the direction of force effects subject to constraints and axes specified.

Step 7: Test for convergence.

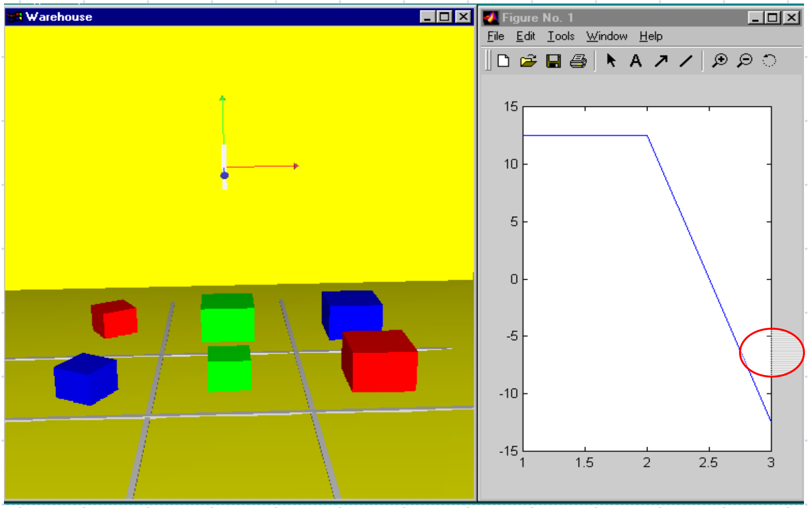


Design space

- This coordinate information of the probe is used to represent design variables.

- The user can perform an exploratory search of the region to arrive at the optimal solution.

3-D cube placement problem



Programming Environment: MATLAB and GHOST on Windows NT

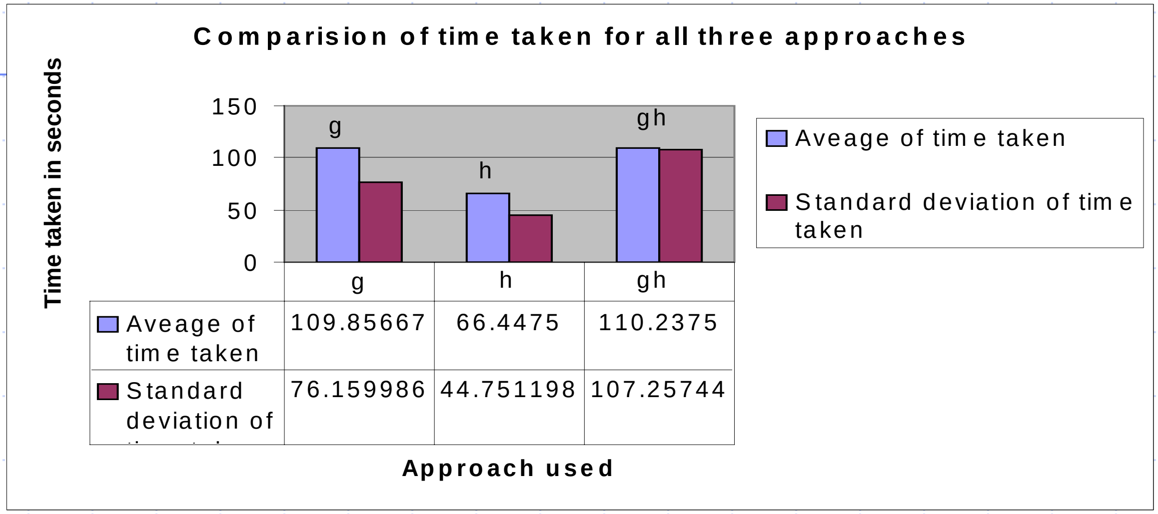
•The user uses the phantom probe to move blocks into cells.

• A cost value is associated with each configuration of blocks.

• Information is represented through interactive plots and/or force effects.

• One set of experiments is complete when an optimal cost is reached.

Inferences



- Force effects provided by the PHANTOM are discernable.

- The combined graphic and haptics approach was preferred by 80% of the users.
- The haptics approach takes lesser time in 66.67 % of cases.
- Haptics provides an efficient duplex sense for decision making.

Uncertainty Display Experiment

With Profs. Ann Bizantz and James Llinas

Experimental Design

- Display of probability: Visual, Tactile, or Auditory
- "Look" before move – make task consistent across modalities
- Tradeoff between risky path and shortest path
- Score motivation: length, time vs. mines "hit"; monetary bonus for high score
- Measure path length, speed, risk, trust in display

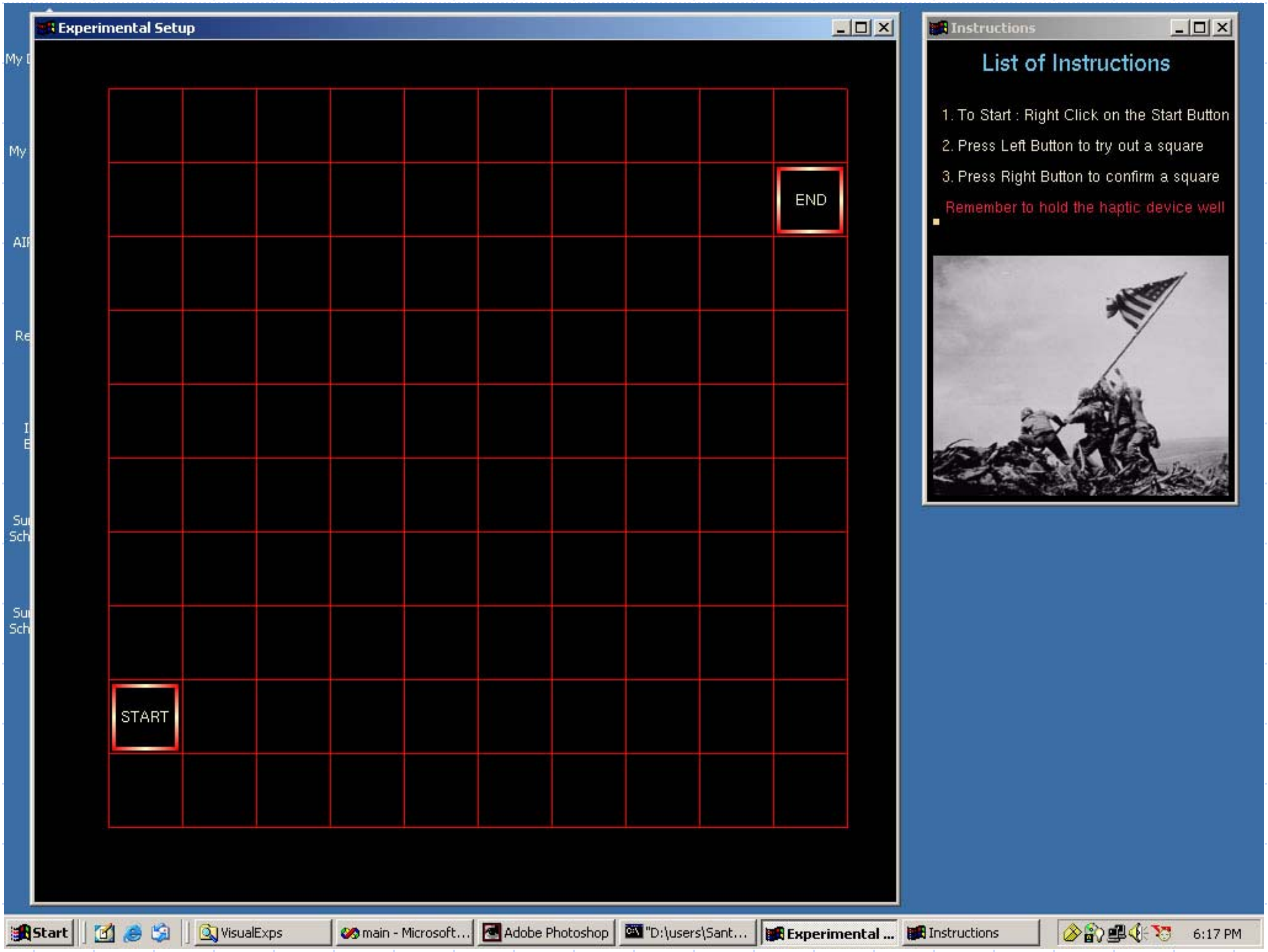
Haptics for Threat Perception

Terrain visualization with distribution corresponding to mine location

Color code corresponds to probability of mine field location between 0 and 1 in steps of 0.1

The user makes a decision depending upon a combination of different Effects namely:

- Visual
- Audio
- Haptic


Experimental Setup
END
START
Instructions
List of Instructions
1. To Start : Right Click on the Start Button
2. Press Left Button to try out a square
3. Press Right Button to confirm a square
Remember to hold the haptic device well
Start
VisualExps
main - Microsoft...
Adobe Photoshop
"D:\users\Sant...
Experimental ...
Instructions
6:17 PM

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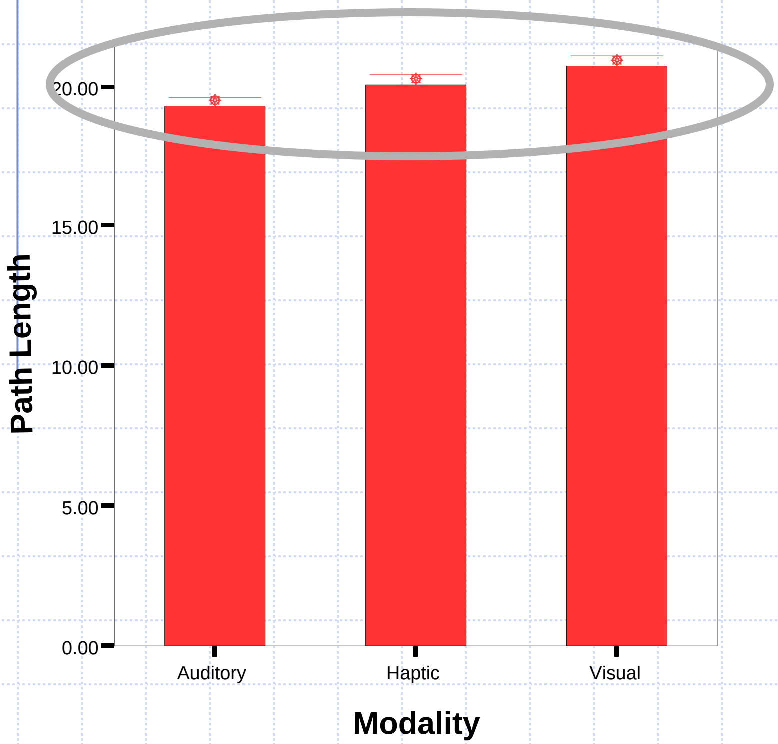
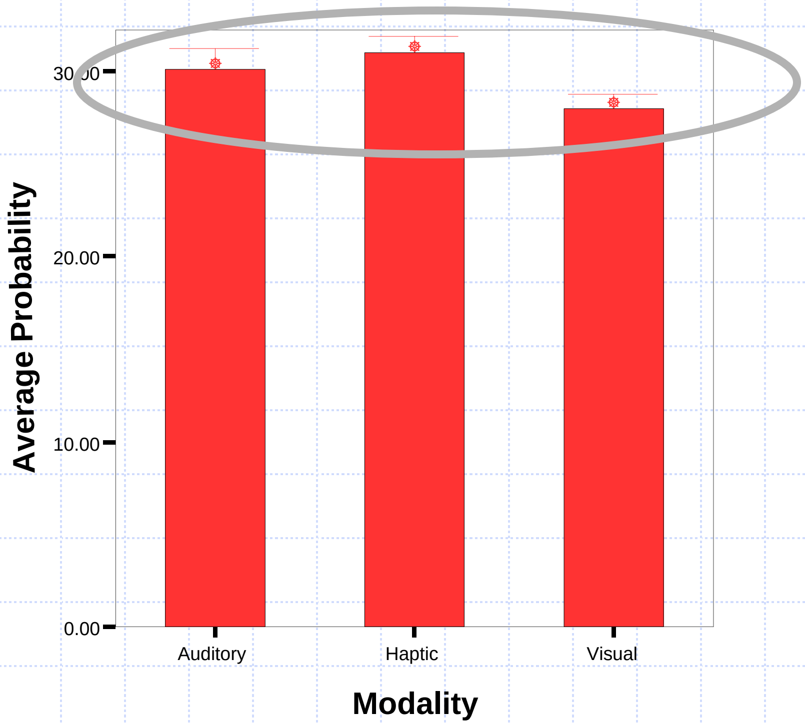
Experimental Design

Training (No display) → Experimental Conditions

	20 trials	20 trials	20 trials
P1	Visual →	Tactile →	Auditory
P2	Tactile →	Auditory →	Visual
P3	Auditory →	Visual →	Tactile

Performance Results





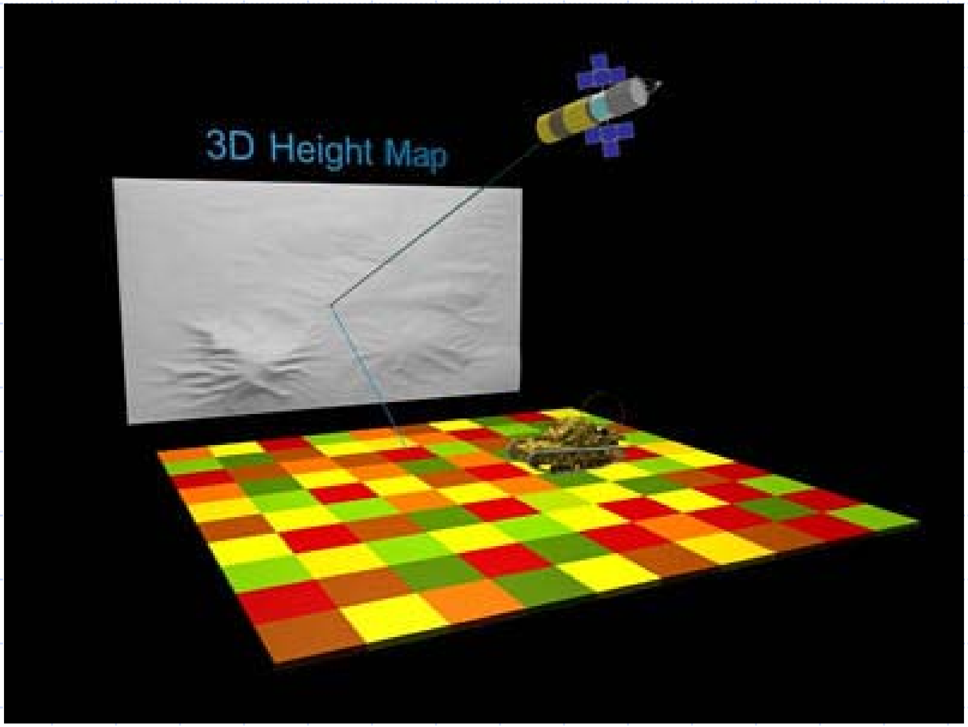
Summary

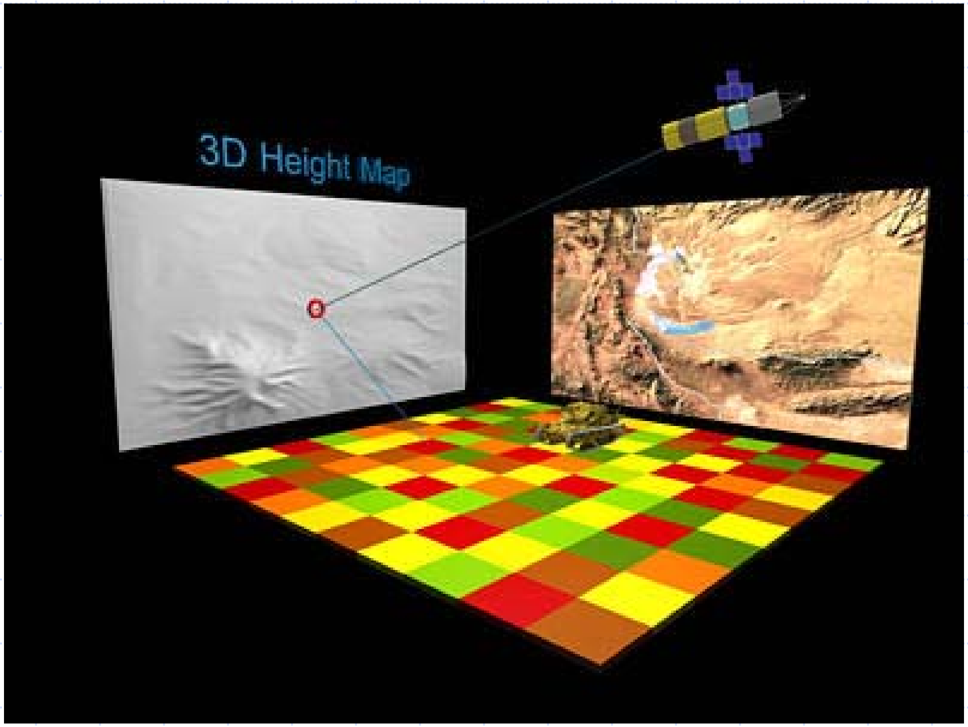
- Visual Condition resulted in more conservative performance - less risk, but longer path length. Auditory condition had shortest path length, but more risk.
- Visual Condition initially faster, but with learning, haptic condition approached these times
- Auditory remained slower
- Overall workload similar, but haptic had higher physical workload, and auditory condition had higher levels of frustration
- Trust similar across modalities, but tended to decrease with time

Observation

- For risk avoidance, visual condition preferable
- For condition where visual clutter is problematic, haptic interface provided acceptable performance in terms of risk avoidance
- Frustration level for haptic interface less than auditory

How haptic maps can be integrated with Visual System

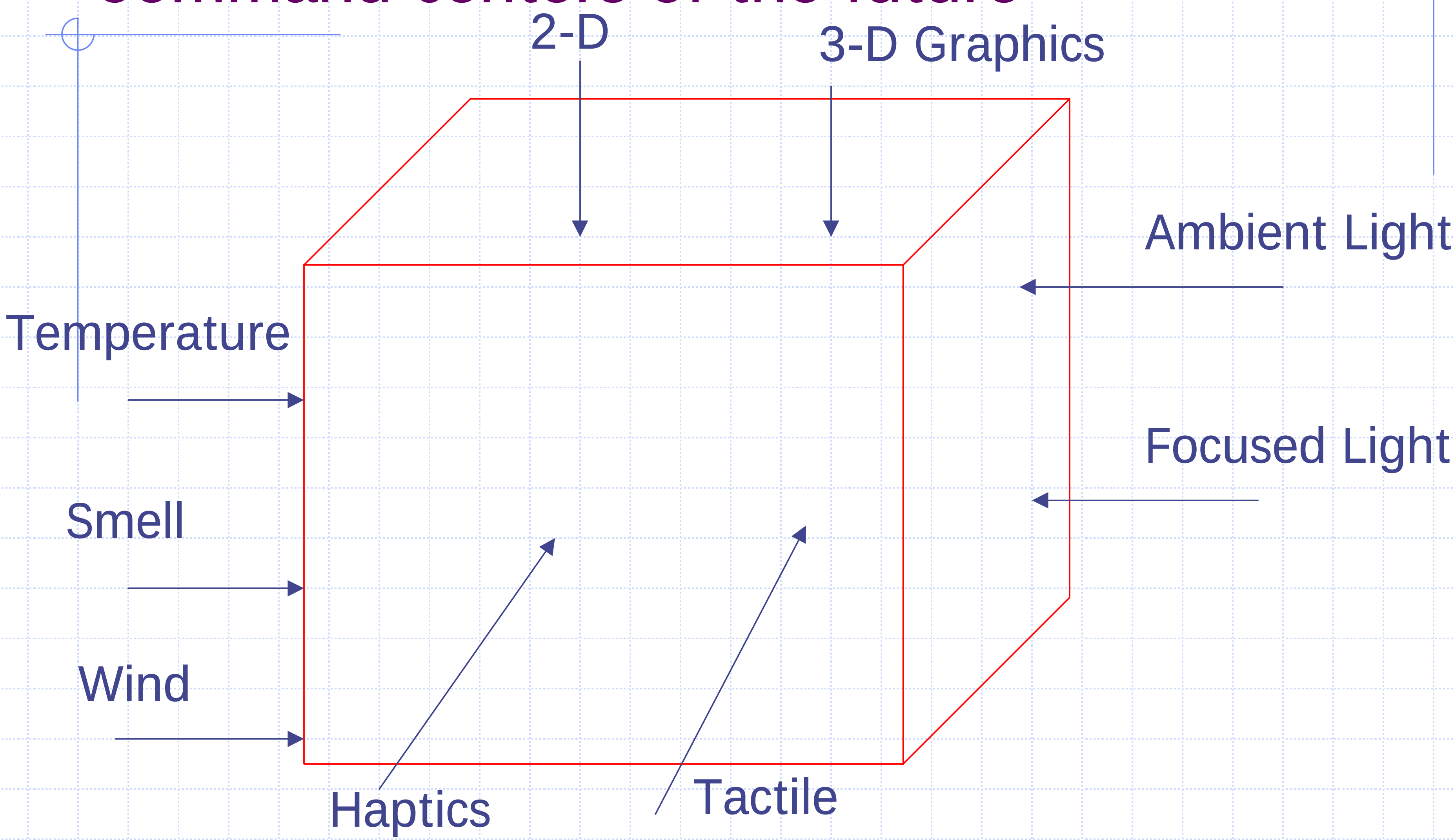



3D Height Map

Various sensory media

- Vibration
- Resistance
- Viscosity
- Temperature
- Wind
- Ambient Light
- Focused Light
- Holography
- Autostereoscopy
- Augumented Reality
- Merged Visual+GUI
- Fishpond VR
- 6-Wall CAVES

Command centers of the future

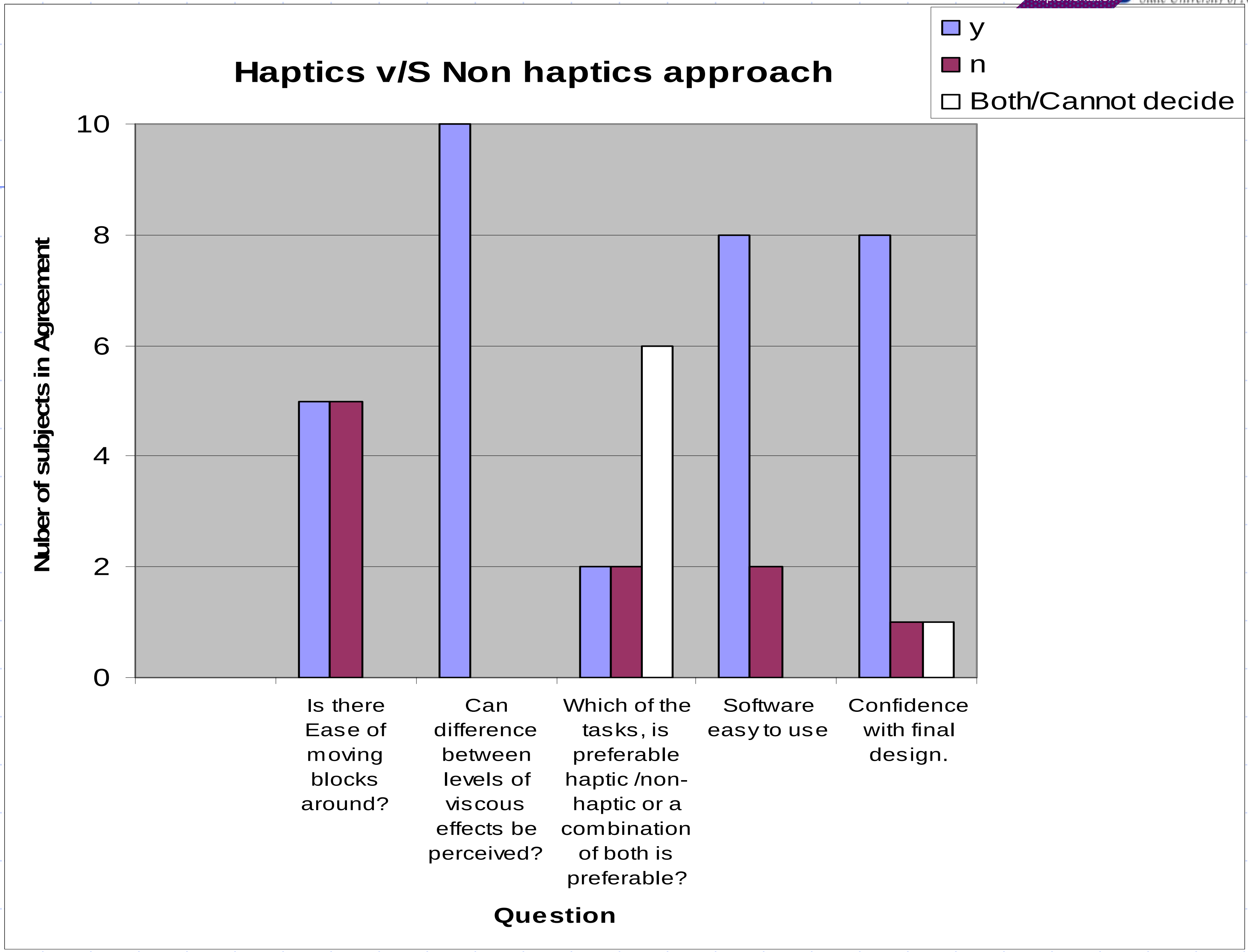


Topics for discussion

- What is the ideal interaction medium?
- Matching mental model?
- What types of other information visualization can be provided?
- Ontology?

Information and modes of presentation

	Vibration	Viscosity	Resistance
Uncertainly			
Constraints			
Boundaries Geography			


Implementation
University at Buffalo
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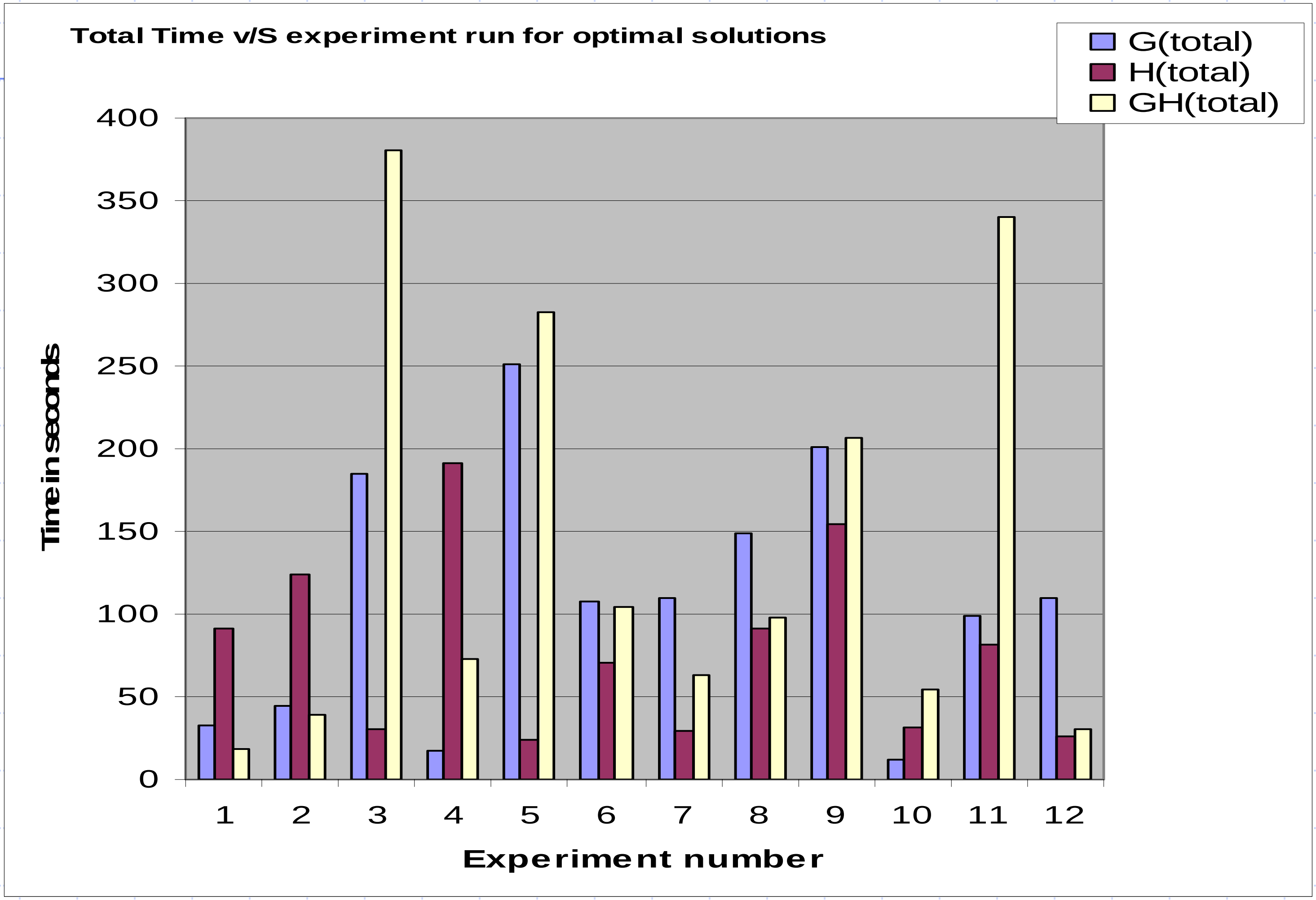
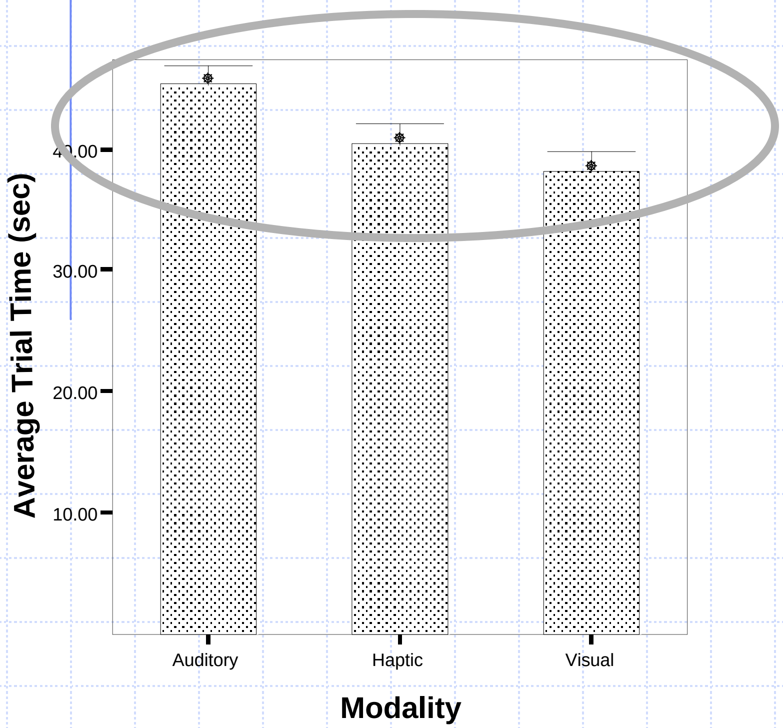
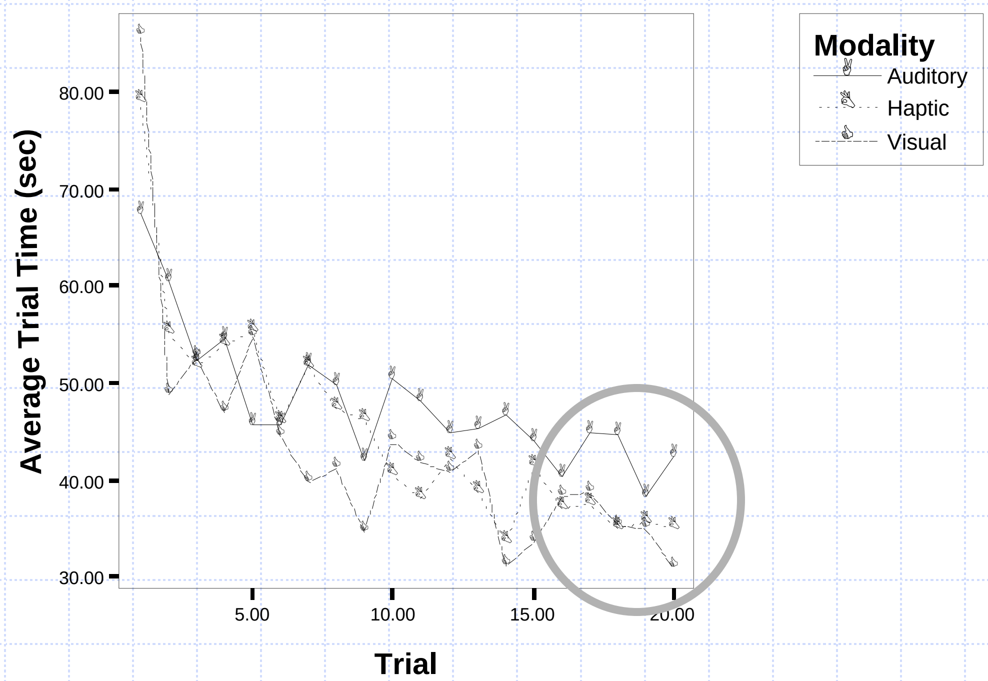
Haptics v/S Non haptics approach
y
n
Both/Cannot decide
10
8
6
4
2
0
Nuber of subjects in Agreement
Is there Ease of moving blocks around?
Can difference between levels of viscous effects be perceived?
Which of the tasks, is preferable haptic /non-haptic or a combination of both is preferable?
Software easy to use
Confidence with final design.
Question

Time as a performance criterion



Trial Time Results





Workload Results